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MUNITION EXPENDITURE MODEL VERIFICATION: KWIK PHASE I.(U)
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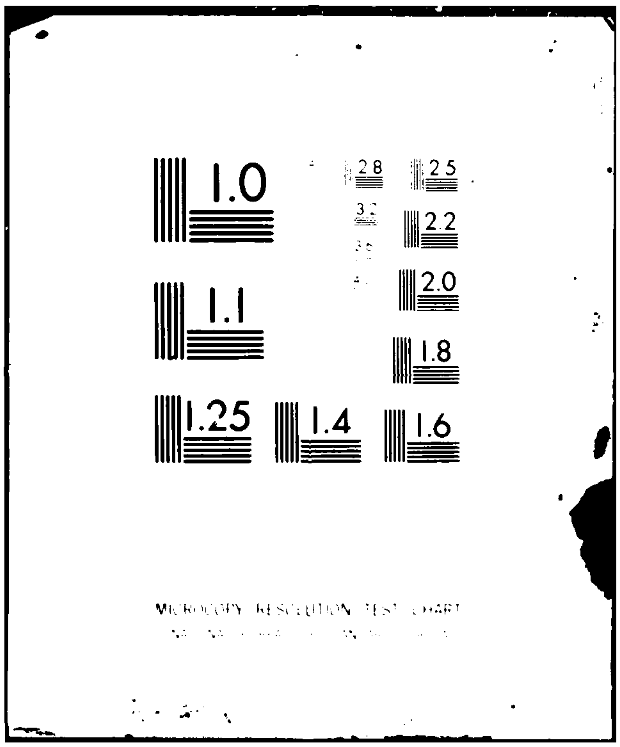
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MUNITION EXPENDITURE MODEL VERIFICATION: KWIK PHASE I (U)

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The threat imposed by the Soviet bloc tank forces requires that ground level obscuration, for both offensive and defensive planning, must receive the most thorough research and developmental efforts. The possibility of reducing costs for munition expenditures further dictates pursuit of more efficient mechanisms for obtaining obscuration objectives.

A large data base from previous experiments exists in the literature, covering chemically generated military smokes. These data have been used to verify and/or evaluate several different approaches to atmospheric diffusion, including the Gaussian formulae. These previous tests have verified the predictability of relatively long average downwind concentrations of some diffusing materials in the atmosphere. However, a deficiency exists in the case of military smokes for which the actual obscuration has not been reliably predicted or verified, especially over short time intervals. This deficiency has made it impossible to evaluate KWIK, a munition expenditure model, in all categories of performance without obtaining additional data.

In order to verify the munition expenditure predictions of the KWIK model, an evaluation plan consisting of three phases was devised by Atmospheric Sciences Laboratory (ASL). This paper deals only with Phase I, an effectiveness evaluation test for visible wavelengths.

1. DESCRIPTION OF MODEL

The KWIK (a mnemonic derived from crosswind integrated concentration) model consists of a blending of meteorological and site parameters, atmospheric optics, and turbulent diffusion theory. Each of these are briefly discussed below.

Meteorological data requirements for the KWIK algorithm are based upon observations that would be available on a modern battlefield (i.e., hourly airway type data obtained from the United States Air Force (USAF) Air Weather Service via the USAF Global Weather Central, or information furnished by the US Army Field Artillery Meteorological Sections).

Observational requirements for the microscale diffusion, atmospheric optics, ambient stability, and wind direction effects upon the obscuring screen were investigated, with the determination being that eight standard meteorological parameters and one terrain characterization index would be sufficient for the KWIK algorithm. The eight meteorological data inputs consist of

a. ceiling height in feet
b. cloud cover in percent
c. visibility in miles
d. precipitation, yes or no
e. temperature in degrees Fahrenheit
f. dew point temperature in degrees Fahrenheit
g. wind direction in degrees (meteorological convention)
h. windspeed in knots

The terrain index is the average height, in centimeters, of the surface roughness elements, such as trees, bushes, grasses, or buildings.

The stability category scheme used is a composite version developed from the published results of Pasquill (1), Turner (2), and Smith (3). The composite approach uses Turner's radiation index, ceiling, and cloud modifications to the index, and Smith's windspeeds associated with each Pasquill category. Other inputs related to the calculation of insolation for the determination of the atmospheric stability category are

a. latitude in degrees
b. direction from equator (north or south)
c. longitude in degrees
d. direction from Greenwich (east or west)
e. altitude above MSL in kilometers
f. Julian date in three digits
g. Greenwich civil time in hours

KWIK contains an optics section that is adapted from an approach to atmospheric transmission by Downs (4). The model assumes that 5 percent (5), (6), or less transmittance will deny acquisition of a target in the

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visible wavelengths. The transmittance of light at various wavelengths through a path is determined by calculating the attenuation due to both absorption by water vapor and scattering by natural atmospheric aerosols. The concentration of smoke necessary to obscure a target through a given line of sight is then calculated, along with the number of munitions necessary to deliver the required amount of obscurant.

For a continuous smoke source, such as the hexachloroethane (HC) used in the KWIK Phase I trials, the smoke is assumed to have a Gaussian distribution and to diffuse independently in three coordinate directions (X, Y, Z). The crosswind integrated concentration (CWIC) equation used is based on the Gaussian distribution function described by Pasquill (1) and Gifford (7) and modified by Umstead et al (8).

2. DESCRIPTION OF TRIALS

Thirty trials were conducted at Dugway Proving Ground (DPG) during July and September of 1980. Groups of three M1 and one M2 HC smoke canisters were statically detonated to simulate each 155-mm M116BE projectile needed during a given screen.

Test Objectives. The objectives of the KWIK Phase I evaluation test were

a. To provide an evaluation of the KWIK smoke model by correlating model predictions of obscuration effectiveness with empirical (observer) data.

b. To collect meteorological, photographic, and observer data in order to characterize the meteorological, environmental, and smoke plume behavior for each trial.

c. To compare and evaluate smoke munition expenditure calculations of the KWIK model from successful screens with those obtained by the current method used by the field army (9), (10), (11).

d. To compare meteorological data from a distant (10 km) source and evaluate its effect on the munition expenditures calculated by the KWIK model.

Data Requirements. The main data requirements consisted of meteorological, photographic, and visual observational data.

Meteorological data were measured at the test site (horizontal grid) from three different towers (figure 1). Two 10-m towers were located at the southeast and northwest ends of the grid, respectively, and a 32-m tower was located on the northeast side of the grid next to the observation post. Upper atmospheric data were collected at the Ditto

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Meteorological Station, located about 10 km east of the test area, at the DPG Ditto Technical Center.

The photographic coverage provided during the trials consisted of three 16-mm color motion picture cameras located as shown in figure 1. Color still photographs were taken every 30 s during each trial with a camera located near the area of the observation post (figure 1).

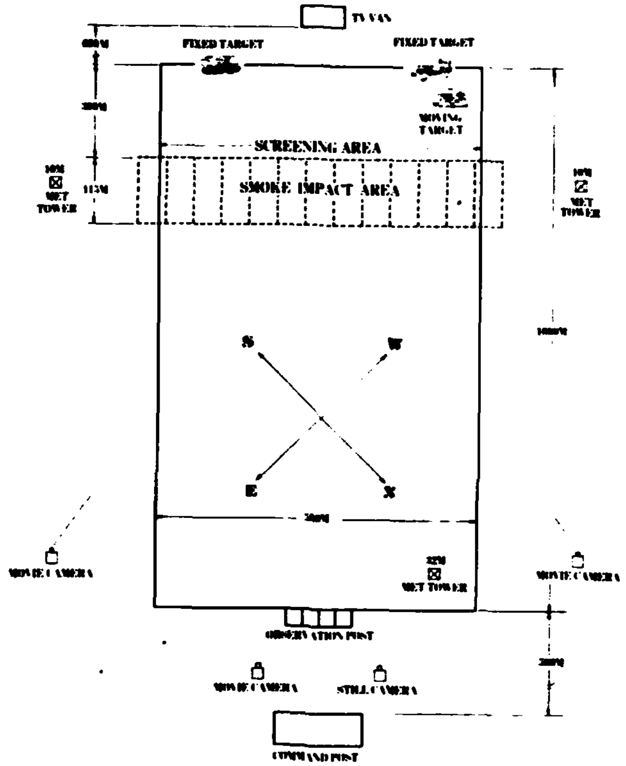

Figure 1. Test Grid for KWIK smoke tests, Phase I, DPG, Utah.

Visible smoke obscuration assessments were made from the observation post. Each observer (with binoculars) was situated in a booth and had an unrestricted view of the target area (figure 1). Each of three observers was assigned one of the three targets, with a fourth observer assigned all three targets. The first three observers activated a recording device when their assigned target was visible. The fourth observer activated a recording device when one or more targets were visible.

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Smoke Impact Area. This area included the screening area plus 30 m to the southeast and to the northwest, for a total of 560 m (figure 1). Each row consisted of three lines (a, b, and c), on which the required HC smoke canisters were placed. The munitions along each selected "a" line were ignited simultaneously, while the ignition of the "b" and "c" lines were delayed by 2-min time intervals. This arrangement was used to simulate volleys of dynamically fired M116 155-mm HC rounds.

KWIK Calculations. An HP85 desktop calculator located at the command post was used to perform the KWIK smoke model munition expenditure calculations. Using the meteorological and site data from the test grid prior to each trial as inputs, the model produced the outputs that were used for the appropriate trials on a real-time basis.

3. EVALUATION OF DATA

A percentage of "effective screening" was calculated by comparing the total time the observers viewed their targets with the maximum time any target was scheduled to be visible. The evaluation of the data was performed in three parts: the Smoke Screening Assessment, the Munition Expenditure Assessment, and the High Wind (>8 m/s) Smoke Screening Assessment. The Smoke Screening Assessment was based on target obscuration data, with the High Wind Smoke Screening Assessment data coming from trials 23 through 30. One Munition Expenditure Assessment compared the KWIK munition expenditures with those obtained using the method in the current FM (FM 6-40-5) (9), (10). Another Munition Expenditure Assessment compared munition expenditure results using meteorological data collected at two sites: the DPG Horizontal Test Grid and the Ditto Meteorological Station. For the purpose of evaluation, all of the test data were grouped according to windspeed as follows: 2.0 to 3.5 m/s, 3.6 to 7.5 m/s, and >8 m/s.

Smoke Screening Assessment. The target observer assessment data were plotted as a function of time. These data were analyzed for all trials, except trials 1 through 4, which lacked observer data. Photographic data from each trial were used to verify the target observer assessment data.

Low windspeed screens (2.0 to 3.5 m/s) were successful in four out of six cases, with an average effective screening during 88.3 percent of the total target time, as shown in table 1. Trials 16 and 18 were unsuccessful because of low windspeeds (<2 m/s), which contributed to excessive plume rise, preventing formation of a screen. Significantly, the FM method's predictions for trials 16 and 18 were identical to those produced by KWIK, indicating that both models were unable to predict an effective screen.

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TABLE 1. SMOKE SCREENING ASSESSMENT, WINDSPEED: 2.0 - 3.5 M/S

Trial No.	Target	Initial Time To Screen Target (min: sec)	Approx Build Up (min: sec)	Target Schedule (min: sec)	Time Target Observed (min: sec)	Effective Screening (%)	Mean Effective Screening (%)
	Tank (T)	*		4:30	0:00	100	
11	Jeep (J)	*		2:30	0:00	100	
	Moving (M)	*		5:00	0:45	85	
	All (A)	*	1:00	5:00	1:42	66	88
	T	*		2:30	0:00	100	
14	J	*	(Target down for entire trial)			—	
	M	2:42		5:30	1:50	100	
	A	2:42	2:42	5:30	0:54	100	100
	T	0.45		6:00	0:45	100	
15	J	1:30		6:00	3:30	67	
	M	2:00		6:00	2:15	93	
	A	2:00	2:00	6:00	3:45	67	82
	T	0:42		6:00	3:18		
16	J	5:00		4:00	2:21		
	M	6:00		6:00	4:24		
	A	6:00	*	6:00	4:45	0	0
	T	*		2:30	0:24	84	
17	J	0:48		4:00	0:48	100	
	M	*		5:00	1:36	68	
	A	0:48	0:48	6:00	2:06	78	83
	T	*		2:00	1:48		
18	J	4:00		5:00	2:36		
	M	4:30		6:00	2:12		
	A	6:00	*	6:00	4:18	0	0

*Cannot be determined

Table 2 contains the smoke screening assessment for twelve trials within the wind regime of 3.6 to 7.5 m/s. The overall effective screening assessment for this group was 99 percent.

Munition Expenditure Assessment. Table 3 shows the number of rounds KWIK predicted would obscure the entire 500 m for 6 min for two wind groups under low humidity (RH ≈ 30 percent) and under high humidity (RH ≈ 80 percent). For both humidity levels in each wind regime, the net gain or loss in munition expenditures is also indicated. In the case of trial 19, for example, the KWIK model predicted 7 munitions for low humidity and 5 munitions for high humidity, while the FM method predicted 12 munitions. This translates to a munition savings for KWIK of 42 percent and 58 percent, respectively. Munition expenditures cannot be obtained from the FM for windspeeds outside the ranges shown in table 3.

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TABLE 2. SMOKE SCREENING ASSESSMENT, WINDSPEED: 3.6 - 7.5 M/S

Trial No.	Target	Initial Time To Screen Target (min: sec)	Approx Build Up (min: sec)	Target Schedule (min: sec)	Time Target Observed (min: sec)	Effective Screening (%)	Mean Effective Screening (%)
	Tank (T)	*		4:30	0:00	100	
5	Jeep (J)	*		2:30	0:12	92	
	Moving (M)	1:12		5:00	0:12	100	
	All (A)	*	1:12	5:00	0:15	95	96
	T	2:00		3:00	2:00	100	
6	J	2:00		5:00	1:18	94	
	M	1:40		3:00	1:40	100	
	A	2:00	2:00	5:00	2:00	100	98
	T	*		2:30	0:00	100	
7	J	1:00		4:00	1:15	94	
	M	*		5:00	0:00	100	
	A	1:00	1:00	6:00	1:00	100	98
	T	*		2:00	0:00	100	
8	J	1:00		5:00	0:00	100	
	M	0:30		6:00	0:30	100	
	A	0:30	1:00	6:00	0:18	100	100
	T	1:00		3:30	0:30	100	
9	J	0:30		3:30	0:00	100	
	M	1:00		5:00	0:00	100	
	A	1:00	1:00	5:00	0:00	100	100
	T	*		3:00	0:00	100	
10	J	0:24		3:00	0:24	100	
	M	0:30		5:30	0:00	100	
	A	0:24	0:30	6:00	0:24	100	100
	T	0:18		3:00	0:18	100	
12	J	1:00		5:00	0:15	95	
	M	*		3:00	0:15	92	
	A	0:18	1:00	6:00	0:18	100	97
	T	1:00		3:00	1:00	100	
13	J	1:24		6:00	1:24	100	
	M	0:48		6:00	0:57	97	
	A	1:12	1:24	6:00	1:27	96	98
	T	0:30		3:30	0:00	100	
19	J	0:30		3:30	0:00	100	
	M	1:00		5:00	0:00	100	
	A	1:00	1:00	5:30	0:18	96	99
	T	*		3:00	0:00	100	
20	J	0:42		3:00	0:42	100	
	M	0:50		5:30	0:20	100	
	A	0:50	0:50	5:30	0:50	100	100
	T	1:30		4:30	0:00	100	
21	J	1:00		3:00	0:00	100	
	M	1:25		5:00	0:25	100	
	A	1:25	1:30	5:00	0:25	100	100
	T	0:24		3:00	0:24	100	
22	J	1:00		5:00	0:00	100	
	M	*		3:00	0:00	100	
	A	0:24	1:00	6:00	0:24	100	100

*Cannot be determined

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TABLE 3. MUNITION EXPENDITURE ASSESSMENT

Windspeed: 2.0 - 3.5 m/s

Test No.	Field Manual	KWIK (RH 30%)	% Change (RH 30%)	KWIK (RH 80%)	% Change (RH 80%)	Wind
11	22	12	+45	8	+64	Qtr/Cross
14	14	8	+43	8	+43	Qtr/Cross
15	8	8	0	6	+25	Qtr/Cross
16	8	8	0	8	0	Cross/Qtr
17	8	9	-12.5	7	+12.5	Qtr/Cross
18	10	10	0	8	+20	Cross/Qtr
		Net Change	+21.4	Net Change	+35.7	

Windspeed: 3.6 - 7.5 m/s

Test No.	Field Manual	KWIK (RH 30%)	% Change (RH 30%)	KWIK (RH 80%)	% Change (RH 80%)	Wind
5	10	9	+10	7	+30	Cross/Qtr
6	10	9	+10	7	+30	Cross/Qtr
7	8	9	-12.5	7	+12.5	Crosswind
8	10	9	+10	6	+40	Crosswind
9	17	18	-6	9	+47	Qtr/Head
10	25	27	-8	15	+40	Qtr/Head
12	12	18	-50	9	+25	Quartering
13	12	15	-25	7	+42	Qtr/Cross
19	12	7	+42	5	+58	Quartering
20	11	12	-9	6	+45	Cross/Qtr
21	10	9	+10	7	+30	Cross/Qtr
22	13	12	+8	6	+54	Cross/Qtr
		Net Change	-2.7	Net Change	+39.4	

For the lower windspeed group, KWIK produced a net gain in munition savings of 21.4 percent for low humidity and 35.7 percent for high humidity. For the higher windspeed group, KWIK produced a net loss of 2.7 percent for low humidity, but a net gain of 39.4 percent for high humidity. As shown in figure 2, KWIK efficiency in munition expenditures improved as the day progressed, when compared to the FM method. This is due to steadily increasing instability from daytime heating. Under the low windspeeds (2.0 to 3.5 m/s), KWIK has the capability of finely describing atmospheric stability, while the FM method has only three gross categories. Under the higher windspeeds (3.6 to 7.5 m/s), atmospheric stability tends to remain relatively constant with daytime heating, and therefore little difference in munitions expenditures is noted in figure 3.

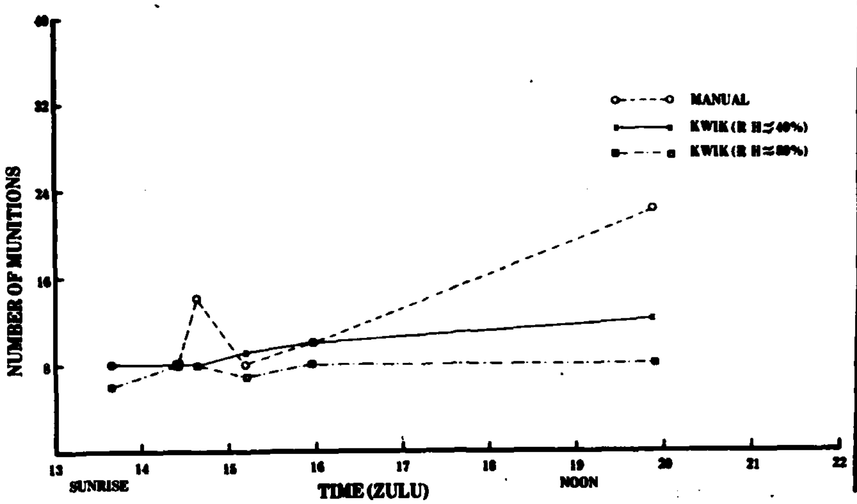

Figure 2. Munition comparison: KWIK vs field manual using Horizontal Grid met (windspeed: 2.0 to 3.5 m/s).

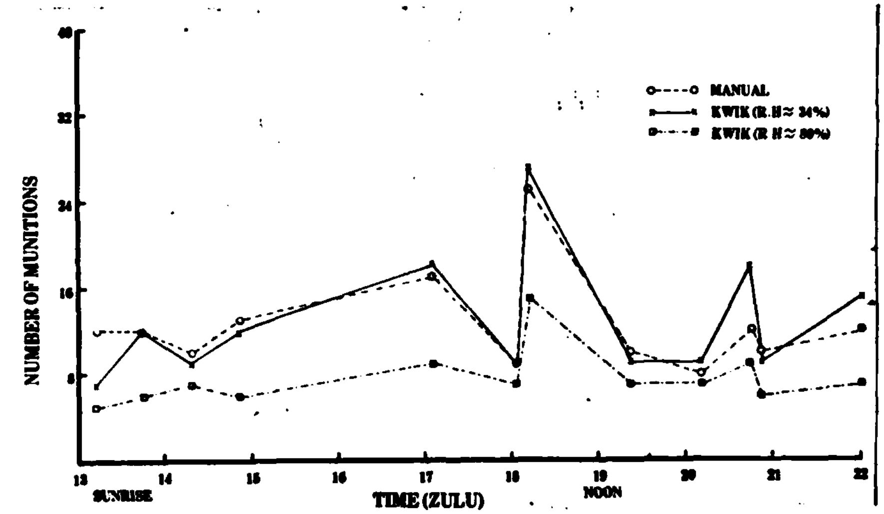

Figure 3. Munition comparison: KWIK vs field manual using Horizontal Grid met (windspeed: 3.6 to 7.5 m/s).

The alternating dash-dot curve in figures 2 and 3 represents the number of munitions KWIK calculated to be necessary to screen at a relative humidity of about 80 percent. KWIK's capability of using the hydroscopic properties of HC smoke enables more efficient use of this munition

when compared to the FM method. This is demonstrated by the consistently lower munition expenditures calculated for all the plotted trials in figures 2 and 3. A net savings of 35.7 percent during the low windspeeds and 39.4 percent during the higher windspeeds could have been realized under these higher humidities. This higher humidity category (RH ≈ 80 percent) is a fairly common occurrence in Europe, especially during the predawn and early morning hours. Under these conditions, KWIK could save a significant number of smoke munitions.

Figures 4 and 5 compare munition expenditure calculations based on both the horizontal grid meteorology and the Ditto meteorology. For the low windspeeds (figure 4) KWIK consistently calculated lower munition expenditures with the horizontal grid meteorology. This calculation is not entirely unexpected, because at low windspeeds local effects caused by terrain features and solar heating tend to dominate the microscale meteorology. For the higher windspeeds (figure 5) there is no apparent mean difference between the two sets of meteorological data, although there were wide differences on any given trial between the grid meteorological data and the Ditto meteorological data. One possible explanation for this variation could be Granite Mountain, which is just a few kilometers southwest through southeast of the grid. This might have set up mountain lee waves with a southeast wind flow, resulting in much higher windspeeds at the test grid than at the Ditto Meteorological Station.

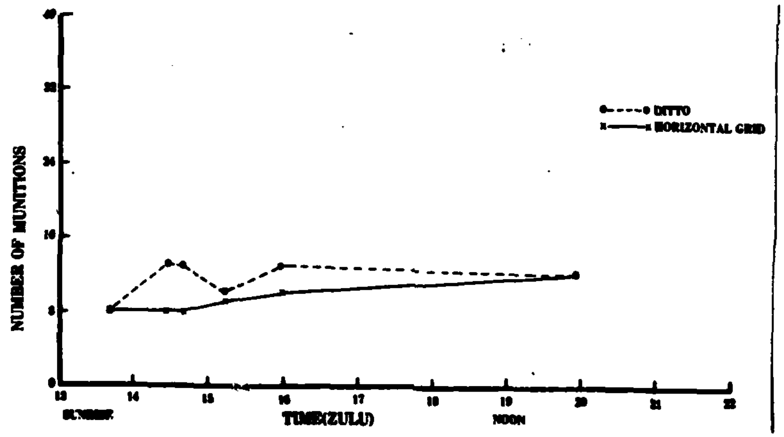

Figure 4. Meteorological comparison: Ditto vs Horizontal Grid met data (windspeed: 2.0 to 3.5 m/s).

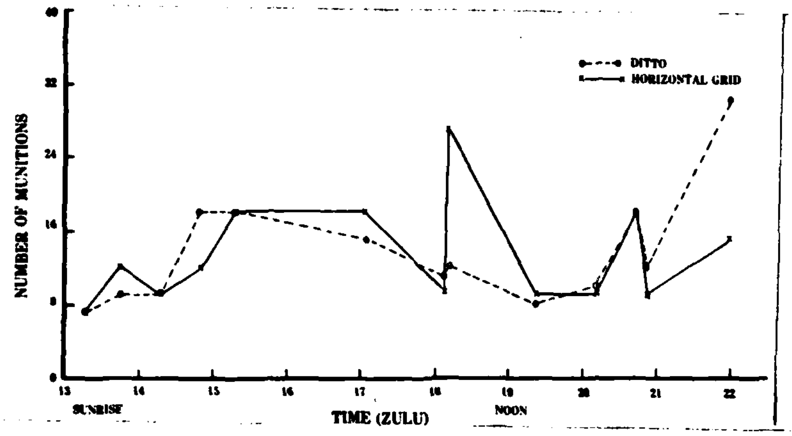

Figure 5. Meteorological comparison: Ditto vs Horizontal Grid met data (windspeed: 3.6 to 7.5 m/s).

High Wind Screening. Trials 23 through 30 were conducted at windspeeds in excess of 16 knots. Army Training Circular TC 6-20-5, entitled "Field Artillery Smoke," indicates that smoke screening at these windspeeds is unfavorable. Nevertheless, it was decided that the testing would continue as long as a successful screen could be deployed, since no other data of this type existed. As shown in table 4A, windspeeds ranged from 18 to 30 knots (8.8 to 15 m/s), with gusts to 40 knots (20 m/s). At these windspeeds a neutral stability was maintained through all trials,

TABLE 4A. WINDSPEED (WS) >8 M/S VS CALCULATED MUNITION EXPENDITURES

Trial No.	WS (m/s)	Rounds Detonated	Rounds Calculated (Grid)	Rounds Calculated (Ditto)	Rounds Calculated (RH ≈ 80%)	Direction
23	9-12	17	18	18	9	Cross/Quarter
24	8.8-12	16.75	18	18	9	Cross/Quarter
25	9.7-13	17	18	18	9	Cross/Quarter
26	8.7-12	15.75	18	18	9	Cross/Quarter
27	11.7-15.5	20	21	18	12	Quarter
28	12.8-18	25.5	27	24	15	Quarter
29	12.3-19.5	25.5	27	24	15	Quarter
30	15-20	41	45*	-	-	Quarter/Head

*Calculated during near gale

as later verified by examining cloud behavior from photographic
ds. The number of munitions calculated (Grid) for the 6-min screens
d from 18 to 45, with the higher figure calculated during a near
with a quartering/headwind direction. Table 4A shows the number of
ions needed to successfully form a screen (from a low of 18 to a
of 27) for trials 23 through 29. The meteorological input from the
Meteorological Station indicated identical munition expenditures
g the morning hours, but somewhat lower amounts during the afternoon
when the winds were higher. Since the higher winds were experi-
at the horizontal grid, probably due to mountain lee waves, it was
surprising to see the slight difference in munition expenditures as
ilated from data taken at the two meteorological stations.

The smoke screen characteristics for the high wind cases are indi-
in table 4B. The build-up time is defined as the time, after T-0,
ired to obscure all targets from the observers' view. The duration
he screen is the time period from initiation of a test to the instant
a target became visible to one or more of the observers. The total
ctive screening time is the total time that all targets were continu-
screened from all observers.

TABLE 4B. SCREEN CHARACTERISTICS

Trial No.	Build Up Time (s)	Duration of Screen (min: sec)	Total Effective Screening Time (min: sec)
23	30	6:40	6:10
24	30	6:50	6:20
25	40	6:40	6:00
26	42	6:45	6:03
27	15	6:55	6:40
28	28	6:50	6:22
29	30	6:40	6:10
30	15	6:45	6:30
Mean	28.75	6:46	6:17

For the eight trials, the mean build-up time was 28.75 s, with a
effective screening time of 6 min and 17 s. In all cases, once the
en had formed there were no apparent holes until the screen began to
k up at the end of the trial. It was surprising to note that the
screens in quality and duration, as judged by observer and photo-
hic data, occurred during the higher winds.

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The similarity of the munition expenditure calculations from both the Ditto Meteorological Station and the horizontal grid met station would seem to indicate that under certain synoptic scale events, the target meteorology is similar to the meteorology several kilometers away. These types of large scale weather systems are not unusual in Europe, especially during the winter months. Another common feature during the winter storms is high relative humidity (RH ≈ 80 percent). Results using such a high relative humidity are indicated in table 4A. All other meteorological parameters are identical. A reduction in munitions of 47.39 percent over the cases with lower humidities illustrates the wide variation possible under varying ambient moisture conditions. This variation is important, considering that the FM method does not have the capability to screen under high winds nor to use the ambient moisture to reduce expenditures under high humidities.

4. CONCLUSIONS

Screening Effectiveness. In this initial phase of testing, KWIK has demonstrated that it not only is more efficient in munition utilization than the FM method, but that it also has the capability to calculate munition expenditures under meteorological conditions that the present FM method considers impractical. For the low windspeed or marginal screening category (2.0 to 3.5 m/s), two trials were unsuccessful in forming a screen because of low windspeeds and extreme variability of wind direction. Since calculations for these same two trials using the FM method produced identical munition expenditures, both techniques failed to successfully screen under these meteorological conditions. The remaining four trials in the low wind category produced a mean effective smoke screen during 88.3 percent of the screen duration time. The few instances during which a target was visible were almost always caused by significant changes in windspeed and wind direction during the course of a trial.

There were twelve trials conducted under favorable screening conditions, with windspeeds ranging from 3.6 to 7.5 m/s. These trials produced a 99-percent mean effective screen. All of these screens would have denied acquisition of a target for the duration of the screen.

Munition Expenditure Comparisons. Phase I was conducted under dry conditions, with an average relative humidity of only 30.5 percent. These dry conditions are important, because HC is a hydroscopic smoke whose screen capabilities are greatly enhanced under the higher humidities that are frequently found in Europe. For the marginal screening category, KWIK used 21.4 percent fewer munitions than the FM method. However, under high humidities (RH ≈ 80 percent), KWIK could have saved 35.7 percent of the rounds that the FM method required for the same missions.

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In the favorable screening category KWIK used 2.7 percent more munitions than the FM method required. However, under high humidities (RH ≈80 percent), KWIK would have produced a 39.4 percent savings in munitions expenditures. The failure to incorporate the relative humidity effects into the FM method clearly causes an excess expenditure of smoke rounds under the higher humidity conditions.

Target Area Meteorology. Under marginal screening conditions, the winds are variable in both space and time. Even under the relatively uniform terrain of DPG, use of the target area meteorology produced a savings in munition expenditures, as shown in figure 4. As windspeeds increase, local wind circulations disperse and the general flow becomes more uniform. During the transition period between low and high windspeeds, tremendous variability can exist over a spatial distance of only 10 km (figure 5). In the wintertime European scenario, major storms covering hundreds of kilometers are quite common. Many of these storms are associated with windspeeds high enough to preclude the necessity of knowing target area meteorology to perform a mission. (This assumes that the terrain features do not dominate the target area meteorology.) Under weaker wind regimes, which occur in Europe during the summer season, local wind circulations would make the availability of target area meteorology desirable or even necessary for the completion of a mission.

High Wind Screening. One of the surprises of Phase I testing was the discovery that it is practical to screen a target during high winds. Eight trials were conducted under high wind (8.0 to 15.0 m/s) or "unfavorable" screening conditions, with a 100-percent mean effective screen. All these screens obscured all targets for more than the required 6 min, as seen in table 4B.

There are several possible reasons for the successful screening at high windspeeds. One plausible explanation is that the vegetation flattens as the windspeed increases, lowering the effective roughness length. This lowering of the roughness length would change the dispersion parameters, which are critical to the correct calculation of munition expenditures. Examining table 4A, it is noted that the actual number of munitions that successfully detonated was always less than the number calculated. Since all of the screens were successful, this overprediction of needed munitions could be due to wind-modified roughness length. Another possibility is the homogeneity of the terrain at DPG. It is possible that for heterogeneous terrain or terrain with extensive vegetation, such as a forest, the increased turbulence at higher windspeeds would preclude the use of smoke. A third possibility is a change in the efficiency of continuous burning smoke munitions during high winds. An increase in the oxygen available to the munition could conceivably improve the efficiency of such munitions.

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Regardless of the reason or combination of reasons for the high wind smoke screening, further investigation is clearly warranted. If future experiments confirm that smoke screening at high windspeeds is feasible, then a change in doctrine would be indicated. This could give friendly forces an advantage in future confrontations using smoke.

6. REFERENCES

1. Pasquill, F., Atmospheric Diffusion, 2nd edition Halsted Press, division of John Wiley & Sons, Inc., New York, 429 pp, 1974.

2. Turner, D. B., "A Diffusion Model for an Urban Area," J Appl Meteorol, 3:83, 1964.

3. Smith, F. B., "A Scheme for Estimating the Vertical Dispersion of a Plume from a Source Near Ground-Level," unpublished Meteorological Office note, 1973.

4. Downs, A. R., A Review of Atmospheric Transmission Information in the Optical and Microwave Spectral Regions, Report 2710, US Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, 1976.

5. Gordon, Jacqueline I., Daytime Visibility, A Conceptual Review, AFGL-TR-79-0257, Visibility Laboratory, Scripps Institute of Oceanography, La Jolla, CA, 1979.

6. Schuppert, G. T., "Visibility Concepts and Measurement Techniques for Aviation Purposes," DOT-TSC-FAA-71-25, Transportation Systems Center, Cambridge, MA, 1971.

7. Gifford, F. A., "An Outline of Theories of Diffusion in the Lower Layers of the Atmosphere," Meteorology and Atomic Energy, D. Slade, editor, US Atomic Energy Commission, Washington, DC, 1968.

8. Umstead, R. K., R. Pena, and F. V. Hansen, KWIK: An Algorithm for Calculating Munition Expenditures for Smoke Screening/Obscuration in Tactical Situations, ASL-TR-0030, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 1979.

9. JTCG/ME, "Summary Tables of Estimated Ammunition Expenditures to Establish and Maintain Smoke Screens," unpublished manuscript.

10. Field Artillery Smoke, Training Circular 6-20-5, US Army Field Artillery School, Fort Sill, OK, 1975.

11. Modern Battlefield Cannon Gunnery, Field Manual 6405, Headquarters, Department of the Army, Washington, DC.

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